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ABSTRACT

This study was originally designed to investigate the effectiveness of using specially adapted, existing programs from the NOVA Television series for helping older citizens to understand the scientific issues that underlie public policy; in particular, to promote understanding of the interdependence of technology development and basic science knowledge and the dependence of critical social decisions on what may appear to be abstract science knowledge. However, in the context of doing the original study, considerable insight into the problems of conducting original research with older citizens was gained. Consequently, this report summarizes this experience as well as presenting results of the television study. Procedures (including selecting NOVA programs, defining scientific literacy objectives, developing revised NOVA scripts/programs, formative evaluation/revision, and conducting the study) are discussed in an introduction. Results are reported as three separate studies: (1) The Port Charlotte Study: Science Understanding from TV Programs by Mature Results (Ernest Burkman and Robert M. Gagne); (2) The Elder Hostel Study: Adult Reactions to TV Science Programs (Ernest Burkman and Robert M. Gagne); and (3) The Tallahassee Study: Adult Retention of Ideas from a TV Science Program (Robert M. Gagne, Ernest Burkman, and Brent A. Hewlett). (JN)

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Promoting Science Literacy in Adults Through Television - Final Report

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Institution: Florida State University
Principal Investigators: Robert Gagne and Ernest Burkman
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FINAL REPORT

PROMOTING SCIENCE LITERACY

IN ADULTS THROUGH TELEVISION

Grant Number: SED 79 20221

FSU Account Number: 122315-218

A. The Problem

This study was originally designed to investigate the effectiveness of using specially adapted existing programs from the NOVA series for helping older citizens to understand the scientific issues that underlie public policy. However, in the context of doing the original study we gained considerable insight into problems of conducting research with older citizens. Consequently, this report summarizes this experience as well as presenting the results of the television study.

B. Procedure

Selecting NOVA Programs For The Study

The first step in the T.V. study was to choose appropriate existing NOVA programs. By "appropriate we meant programs that rather explicitly showed (1) the interdependence of technology development and science knowledge, and (2) the dependence of critical social decisions on what may appear to be abstract and isolated science knowledge. To make the selection, we followed the following three-step process:

a. A catalog of all existing NOVA programs was obtained from WGBH, the public television station in Boston that developed the NOVA series.

b. From brief descriptions in the catalog we identified all programs that appeared to fit our general criteria most closely. Transcripts for these programs were obtained from WGBH.

c. After close examination of the scripts, the number of appropriate programs was reduced to four. These were "PILL FOR THE PEOPLE", "THE GREEN MACHINE", "WILL THE FISHING HAVE TO STOP", and "THE INSECT ALTERNATIVE". Video cassette tapes of these programs were then obtained from WGBH. Further, analysis led us to drop the program "THE GREEN MACHINE". Thus the final selection of programs numbered three.

Defining Scientific Literacy Objectives

As was indicated earlier, the overall aim of the study was to try to use adapted NOVA programs to promote understanding by mature adults of (1) the interdependence of technology development and basic science knowledge, (2) the dependence of critical social decisions on what may appear to be abstract science knowledge. Once the appropriate NOVA programs had been selected, we turned our attention to pinpointing the specific aspects of the two general propositions that we aimed to teach. Our goal was to compile a list of statements about science that are encompassed by the two general goals with which we began and that were dealt with in the NOVA programs selected. This analysis resulted in a list of eleven statements organized under the following three headings: (1) the nature of science, (2) the nature of natural processes, (3) science and society. These content statements, which are included as Appendix A

were then further refined into a list of twelve "domains for test items" (Appendix B). The statements and domains were the basis for adapting the NOVA programs and for developing the tests that would be used to measure learning gains.

Developing Revised NOVA Programs Scripts

Teaching adult citizens the concepts included in the final version of the content statements was the specific goal toward which the revisions of the selected NOVA programs were directed. To reach this goal we first had to analyze the scripts and tapes to find instances in which one or more of these concepts was dealt with explicitly or implicitly. We also looked for fairly long stretches of script that contained no relevant materials. We then wrote inserts for the existing script. The inserts were designed to call attention to the concept being dealt with and to make its treatment more explicit.

Developing The Revised NOVA Programs

When all supplemental materials had been developed and built into the existing script we found that the length of each script had been increased by at least 25%. Earlier conversations with older citizens had convinced us that documentary programs such as NOVA were unlikely to hold the attention of many individuals in this group for more than 30 minutes. Thus we decided to reduce the length of both the original program and the script for the modified version. This was done by excising long stretches of materials that were irrelevant to the concepts in which we were interested. Since the NOVA programs originally selected consisted of a series of discrete segments, it was possible to remove portions of them without unduly interrupting their continuity. The products of this operation were (1) a shortened and focused tape of each

of the three original NOVA programs, (2) a script for a revised version of each that emphasized the concepts that had been identified.

Formative Evaluation and Revision

Once the script for the revised programs had been completed, pilot video tapes were prepared. The pilot consisted of segments showing a graduate assistant narrator saying the new material. These segments were interspersed at intervals through the shortened original program.

The pilot tape was then shown to individuals and groups of older citizens in Tallahassee, Florida for reactions and comments. Reactions were collected by means of a structured interview supplemented by open-ended responses. Also a brief test was given that aimed to measure how much the participants had learned about the concepts identified. Our purpose was to pinpoint problems that could be ironed out before the final tape was made.

During the field test of the pilot tapes we encountered the first of what was to be a series of problems in obtaining participants for the study. Several persons who were approached and asked to view a tape, comment upon it, and be tested on its content, refused to do so. Others who did volunteer walked away before the tape was complete and refused to offer comments or to take the test. The reasons for the refusals fell into two general categories; (1) television was perceived by some individuals as an entertainment medium while documentary programs were not perceived as entertainment; (2) some individuals refused to be "guinea pigs" especially with regard to having to take the tests.

Comments and test scores collected during the field test of the pilot tapes were used to adjust the tape scripts. The adjustments were aimed primarily at increasing interest in the subject and in clarifying

explanations of key points. The revised script then became the basis for the tapes used in the final experiments.

To narrate the final tape we obtained the services of "Red" Barber, a well known sport broadcaster who has retired and now lives in Tallahassee, Florida. Mr. Barber was chosen because he is a competent narrator and also because he is a well know contemporary of the older persons for whom the tapes were developed. It was assumed that Mr. Barber's presence would increase the viewer attention to the tapes.

Conducting The Study

The original plan for the study was to show the original and modified versions of the three tapes to groups of volunteers in retirement communities in various parts of Florida. We planned to communicate with service agencies within the communities for help in obtaining volunteers and space for the showing. The showings were to be in local classrooms equipped with multiple T.V. monitors to facilitate easy viewing. Several showings of different tapes were to be arranged, with each individual signing up for the session that was most convenient. After each showing the attitude measure and the appropriate test was to be administered. Coffee and doughnuts were to be offered as inducements to volunteers.

It quickly became apparent that it would not be possible fully to carry out the original design. We approached the directors of adult education centers in Port Charlotte and Sarasota, Florida about helping with the study. The idea was well received, however, when these individuals sent out requests for volunteers, the number of respondents was so low that it was necessary to cancel the plans for the showings in both communities.

Subsequent conversations with people on the Port Charlotte and

Sarasota adult education centers suggested that the situation in Sarasota could not be salvaged. However, the key person in Port Charlotte felt that he could recruit enough volunteers for a session later in the school year if he made a few changes in the way volunteers were approached. In particular, he suggested that he would have to "sell" the program as being personally useful to the viewers as distinguished from his earlier attempts to influence people on the basis that they would be participating in an experiment that would likely lead to an improved television program for adult citizens. This second recruiting venture succeeded in attracting 94 volunteers who then came to the Port Charlotte Community Center for viewing and testing. This effort became the first part of the study and the results are presented in Part C (The Port Charlotte Study) of this report.

After the disappointing initial results in Port Charlotte and Sarasota we began to search for other ways of obtaining a sample of viewers. Two ideas were explored. First, we got in touch with a number of cable T.V. companies in the Miami, Florida area concerning the possibility of showing the films on the community service channel for home viewing by older citizens. Although it would have been possible to get time on the channel, this option was dropped because of legal problems associated with the ownership of copyrights associated with the NOVA programs and with the logistics of administering tests to persons scattered across Miami. The second idea was to use the participants in an Elder Hostel course scheduled to be presented later in the year at South Georgia College in Douglasville, Georgia. This approach was ultimately rejected because of lack of interest among the enrolleesin the course in being study participants. Reasons for the lack of interest were similar to

those expressed earlier in Tallahassee, Sarasota, and Port Charlotte.

Although our contact with South Georgia College was unsuccessful in generating a sample for the study, we concluded that the Elder Hostel programs offered promise for meeting our needs. Consequently, we contacted Florida State University officials about organizing a local Elder Hostel Program focusing in science to be given during the summer of 1981. Our plan was to build the viewing of the NOVA tapes into the instruction, thus, obtaining a "captive audience" as a sample. The idea was accepted and two identical one week programs were arranged. Both courses were oversubscribed and 30 mature adults arrived on campus in June of 1981 for the first week's instruction. The plan was to have this group view the tapes and take the tests as a part of their instruction and to have the 32 individuals who were to arrive on campus the next week do the same. The events that followed constituted part of the study and are described in Part D (The Elder Hostel Study) of this report.

Finally, we requested help in recruiting additional volunteers for the study from the Senior Citizens Council in Tallahassee, Florida. After some difficulties 59 volunteers were convinced to come to the Senior Citizen Center for viewing and testing. Part E of this report (The Tallahassee Study) describes the results of this work.

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THE PORT CHARLOTTE STUDY

Science Understanding from TV Programs by Mature Adults

Ernest Burkman and Robert M. Gagné
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ABSTRACT

Groups of adults from a retirement community volunteered to view a TV science program. Ages of viewers ranged from 50 to 80, with a preponderance in the 60's. Using random assignment of groups in six small-group sessions, one set viewed the NOVA program The Insect Alternative, while another set viewed an "elaborated" version of this program. Elaboration consisted of the insertion of segments using intentional learning procedures to teach about the process of natural selection and some of its social effects. To a degree having statistical significance, the group viewing the elaborated version learned these added aspects of scientific literacy, while showing no lessening of their favorable attitude toward the program. Other factors such as age, amount of education, and pre-retirement income level had no significant effects on the outcomes of the learning.

THE PORT CHARLOTTE STUDY

Science Understanding from TV Programs by Mature Adults

Ernest Burkman and Robert M. Gagné

Florida State University

Broadcast program offerings in educational television include a fair amount of content pertaining to science. Besides the best known and highly popular NOVA series, scientific information often occurs in, or makes up, educational television programs in such series as Connections, National Geographic Specials, Cousteau Odyssey, among others.

Programs of this sort are developed and produced within a milieu holding to a tradition of entertainment excellence. As Gallagher (1978) points out, the customs and procedures of this tradition are quite different from those which obtain to television programs designed specifically for instruction.

It is difficult to cite well-known examples of science programs that fall into the category of instructional (as opposed to educational) television. There are several programs of this type available for classroom showings, but they do not appear to be widely used at the present time. For a more widely known example, one thinks back to a series called Mr. Wizard, appearing on broadcast television several years ago.

The "entertainment tradition" of educational television exhibits high levels of virtuosity in capturing and maintaining audience attention. This is an important and valuable capability for the production of TV programs, as is generally acknowledged. However, other desirable aspects of educational programs may be less readily incorporated in the process of program development, particularly when the main purpose is the delivery of instruction. Program features which may specifically be difficult to reconcile with entertainment TV production center about the nature of instructional objectives.

Generally speaking, ETV programs dealing with scientific subjects tend to be (1) highly factual in content, and to convey (2) a description of attitudes of a segment or group of the population. Illustrations of the latter are farmers' attitudes toward pesticides, astronomers' attitudes toward space exploration, parents' attitudes toward boy and girl children. These programs communicate much information about what scientists have found, a little about how they have gone about making these findings, and a fair amount about what they imply regarding the attitudes (values) of certain groups in our society. It is notable, however, that these programs do not, in general, communicate "the strategies and tactics of science", the attitudes of scientists toward their respective disciplines, the role of science in society, nor public issues involving science.

Scientific Literacy

It seems possible that the entertainment format of ETV science programs tends to favor content which is unable to teach "scientific literacy". Content of such programs tends to be highly factual, and to emphasize the outcomes of scientific activity along with their applications. In contrast, instruction in scientific literacy might be expected to deal with such matters as the differences in basic and applied research, the tactics of scientific activity, the ways that science interacts with a nation's economy, the sources of support for scientific research and product development. In its broad meaning, then, "scientific literacy" covers a great deal of ground.

The extent of scientific literacy attained by a socially aware scientist who has pursued research in his discipline for twenty years or so cannot reasonably be expected to be acquired by the non-scientist adult of mature years. What does seem reasonable, however, is that such adults might be able to learn from ETV science programs some ideas about science and its social consequences which go beyond the facts and concretely described events that constitute the literal content of such programs.

Intentional and Incidental Learning

When entertainment goals prevail in the production of educational television, the learning which results from TV viewing is termed <u>incidental</u> (Comstock, 1978). Much can be

learned by way of incidental learning. In general, however, the amount of cognitive content learned is less than when learning is intentional. In the latter condition, the learner deliberately brings to bear processes over which he has some control, such as the allocation of attention, the selection of encoding schemes, the confirming of cues to retrieval of what is being learned, and the provision of self-reinforcement. Processes such as these are prominently featured in modern theories of learning of the information-processing type (Anderson, 1980; Bower & Hilgard, 1981).

Presumably, the conditions of intentional learning enable the learner to bring to bear a number of important resources on the learning task, in the form of "control processes" which are available for influencing the ease and effectiveness of learning. In order to do this well, however, the learner needs to be made aware of these processes and of their potential effects on learning. Knowing about these learning processes is called metacognition (Flavell, 1979), and is a kind of awareness that surely distinguished intentional from incidental learning.

Learning in Older Adults

Age differences in learning and memory are not overwhelming, and are often uninterpretable in their educational implications. Older learners apparently learn less well when the imposed pacing of tasks is too fast (Arenberg and Robertson-Tschabo, 1977). Craik (1968) found that older learners fail to use redundant passages in a text to advantage in learning, whereas younger learners may do so. Generally, meaningfully organized passages and tasks tend to be learned best by older adults (Hulicka, 1967).

While older learners are generally believed to be less successful at retrieval of learned material, research findings on this matter are curiously uninformative. Learning may suffer in older learners from limitations in the division of attention (Craik, 1977). Some difficulty in organizing what is learned for retention and transfer of learning has also sometimes been noted (Hultsch, 1974). On the whole, however, within normal limits of well-organized learning material of high meaningfulness, the evidence will permit no expectation of learning deficiencies on the part of older adults. Besides the metacognitive knowledge (Flavell, 1979) that may be brought to bear, the advantages for new learning of a vast amount of previously stored information need also to be noted (Lorge, 1965).

Purpose of the Study

The present study was undertaken to determine whether inserted content designed to elaborate on the instruction of a TV science (NOVA) program, aimed at teaching some aspects of "scientific literacy", could accomplish the purpose of increasing such knowledge in a group of mature adult viewers. The viewers, aged 50-80, watched the programs in small groups assembled in rooms of the community center of a retirement community. The learning outcome of a group which saw the elaborated version of a NOVA program was compared with that of a similar group which viewed the unelaborated version.

The elaborated version of the NOVA program The Insect Alternative was designed to augment the learning by means of statements, comments, and questions delivered via the sound

track. These insertions had two purposes:

(1) to encourage the use of learning control processes (metalearning) available to the viewers; and

(2) to provide added knowledge of the sort which could be classified as "scientific literacy".

In view of the broad meaning of scientific literacy, it was obviously possible to select only certain knowledge components to represent this concept in the present study. Furthermore, it was necessary to elaborate ideas which were contained in the specific NOVA program chosen for the study, The Insect Alternative. We chose to provide elaborated instruction on the process of natural selection, as illustrated by the development of strains of insects immune to certain pesticides, and the social implications of this process, as it pertains to the control of harmful insects. Evidence was sought of improved understanding of these aspects of science, attributable to the effects of the inserted elaborative instruction.

Method

Participants

The viewers participating in the study were residents of a retirement community in Port Charlotte, Florida. Their ages ranged from 50 to 80, with a large preponderance in the 60's. Included were people who previously held blue-collar and tradesman jobs, as well as some professionals. One subset viewed an elaborated version of the television program, and another subset a "straight" version of the same program.

TV Programs

The unelaborated version of The Insect Alternative was [illegible]y this program as it is shown on a television screen from a video tape. Beginning with the cotton boll weevil, the program gives an account of a number of different insect pests and of ways that have been invented to control them. It recounts the events of resistant strain development that followed widespread use of DDT and other pesticides. Other methods of control, including the occurrence of predators and events which interrupt the life cycle are also discussed.

The elaborated version was designed to teach the process of natural selection, its relation to pesticide use and the occurrence of resistant strains, and some of the social implications of these phenomena. Instructional material covering these ideas was introduced via an added sound track, at points in the program which could serve as examples. In addition, material was introduced to convey the notion of metacognition (Flavell, 1979), by reminding the viewers of strategies which could be used to learn and remember. Several instances were included on on-screen self-check questions, of the true-false type. These asked the viewers to think of the answers to questions, followed by sound track statements providing "corrective feedback". The sound track was narrated by Red Barber, a retired sports announcer whose voice was familiar to many of the participants.

Knowledge Test

Towards the end of the TV program, viewers were given practice on a style of questioning which was to carry over to

the knowledge test. On the screen appeared the two newspaper headlines: (1) Staph Epidemic in Local Hospital, and (2) Trout Returning to Lake Michigan. Brief accounts were given of these events, illustrating aspects of the process of natural selection. True-false questions were asked, and corrective feedback given via the sound track. Following this, the test of knowledge was presented. The screen was made to show three different newspaper headlines, each of which was followed by an account of a phenomenon which exemplified some principles of natural selection. A one-page test of printed true-false questions was designed to assess the viewers understanding of these phenomena. The three headlines were: (1) Citizens Fight Elm Bark Beetle; (2) Weeds Mimic Flax Seeds; and (3) Fire Ants Menace Farm Planting.

Knowledge objectives reflected in the end-of-program test dealing with natural selection were as follows:

a. Individuals of any kind of plant or animal vary in their ability to survive exposure to lethal agents or conditions. For any particular agent or condition, some resistant individuals are likely to be totally immune to damage.

b. Exposure of individuals of a species to a lethal agent or condition, typically results in an initial decline in the population. This decline results from the death of the most susceptible individuals. However, a number of resistant individuals tend to survive.

c. Later, the number of individuals increases to a normal-sized population, owing to rapid reproduction among the survivors.

d. Since the offspring of resistant parents tend to be resistant, future generations exposed to the lethal agent or condition tend to be resistant to that agent or condition.

e. As shown in the program, chemicals used to kill insects work in the short run, but in time the number of insects returns to normal, because resistant strains appear. Controlling insects by large doses of chemical pesticides is not an effective procedure; other methods need to be developed and used.

Attitude questionnaire. An attitude questionnaire was designed to be mailed out to the participants about two weeks following their viewing of the program. This 17-item questionnaire was adapted from the Silance and Remmers "Attitude towards any school subject", as described by Shaw and Wright (1967). Statements to be checked on this scale range from the highly favorable "No matter what happens, this program would always come first" to the very unfavorable "I would look forward to this program with horror". The statements are scored in accordance with a weighted scale derived from administration to college students. For purposes of the present study, no reason was seen for developing new scale scores. Otherwise, the items were modified to refer to "this program" rather than to "this subject".

Procedure

Each of the programs, the unelaborated and the elaborated, required about 55 minutes' viewing time, including the time for completing the true-false test. In addition, a sheet of personal information was collected (age, previous income, highest grade [illegible] ucation).

Over two days, six small-group viewing sessions were held. On each day, one session was scheduled for mid-morning and two for the afternoon. Numbers of viewers in these sessions varied from 7 to 21. Random assignment was made of each session to one of the two program versions. No reasons are known why selective factors associated with the session schedule should have any biasing effects.

Numbers of participants in the two groups viewing different versions turned out to be 56 for the elaborated version, 38 for the unelaborated.

Results

Comparability of Groups

The comparability of groups which viewed the unelaborated and elaborated versions of The Insect Alternative is shown by the data of Table 1. As can be seen,

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Insert Table 1 about here

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in both age and income the groups turned out to be closely similar. In pre-retirement income, however, a difference appeared which needs to be taken into account in the significance test applied to scores of the two groups on the knowledge test.

Attitudes

Mean scaled scores and standard deviations for the attitude questionnaire are given in Table 2.

Insert Table 2 about here

These values are based upon returns of 40 people (71%) in the group which viewed the elaborated version, and 29 people (76%) in the group which saw the unelaborated version. Since the favorable attitude scale of this questionnaire ranges from (neutral) to (highly favorable), it is evident that both programs made favorable impressions on their viewers.

Table 1

Means and Standard Deviations of Values of

Personal Variables Obtained from Participant Reports

	Age		Education		Pre-Retirement Income	
Group	M	S.D.	M	S.D.	M	S.D.
Elaborated Program N=56	66.50	6.37	13.73	3.09	19.83	6.54
Unelaborated Program N=38	65.53	8.69	13.74	2.57	16.74	6.36

Table 2

Means and Standard Deviations of

Scaled Scores on the Attitude Questionnaire

Group	Per Cent Responding	M	S.D.
Elaborated Program N=56	71%	8.89	1.55
Unelaborated Program N=38	76%	9.13	1.23

A t-test applied to these data yielded a value of , well above the alpha level of .05 as an indication of significance of the difference in means. There is no evidence here, then, that either program gave rise to a reaction more favorable than did the other.

Knowledge Test (Process of Natural Selection)

Scores of the two program groups on the knowledge test on the process of natural selection are shown in Table 3.

Insert Table 3 about here

Obtained mean for the group which viewed the elaborated program is higher than the mean for the unelaborated program. If allowance is made for chance scores on the 19-item true-false test, the percent advantage in knowledge of natural selection is 17% for the elaborated-program groups.

Significance of differences in mean scores of the groups were tested with a t-test. For the raw means, t was found to be 2.90, df=92. For the adjusted means, taking account of initial differences in the income variable, t had the value of 2.86, df=92. These values permitted a rejection of the null hypothesis, using an alpha level of .05 and a two-tailed test. The advantage in knowledge of natural selection for those who viewed the elaborated program is a significant one.

Table 3

Means and Standard Deviations of Scores of the Two Groups of the Experiment on the Knowledge Test

Group	Obtained Score		Adjusted Score	
	M	S.D.	M	S.D.
Elaborated Program N=56	15.27	2.06	15.24	2.06
Unelaborated Program N=38	13.71	3.10	13.75	3.10

Discussion

It appears from these results that people of retirement age who have volunteered to view a TV program about science can acquire a degree of scientific literacy which goes beyond that which they obtain from a very good example of a typical science "documentary" program.

The Insect Alternative is an excellent science program of the NOVA series. It has been prepared, of course, in accordance, with production practices and standards that generally prevail in the educational TV industry. It contains many details about scientific research, the work of scientists, and what Conant (1947) might have called the "tactics" of science. Much can be learned from viewing such a program, all of it by what is called in learning research circles "incidental learning".

Viewers learn by incidental learning when they devote attention to comprehension of the message being delivered via TV, but make no further effort to involve the processes of learning and retention. Intentional learning, in contrast, occurs when learners deliberately manage their own processes of selective perception, semantic encoding, and cue selection while viewing a TV program. The process by means of which they do this is called metacognition (Flavell, 197 ; Brown, 1978) and is presumed to call into play those internal processes called "control processes".

Learning may take the form of intentional learning when the learner, of her own volition, employs control processes to bring into play strategies that enhance the processes of

learning, or when the instruction supports such processes directly. An example of the latter sort is the provision of corrective feedback, which can be done with precision only when supplementary materials (such as booklets for viewer responses) accompany television programs.

Results of the present study demonstrate that "metacognitive" additions to an educational TV documentary, having the purpose of producing intentional learning on the part of adult viewers, produce learning of certain aspects of scientific literacy. These new learnings amount to an improved understanding of the process of natural selection and some of its social implications. Of course, these new elements of scientific literacy were added — they were simply not present in the original TV version, or at least were not apparent to the viewer who is a non-scientist.

The main point to be made is surely not that something new was learned because something was added to the original TV documentary. The addition, however, took the definite form required for intentional learning, and thus it contrasted with the kind of learning embodied in the original "unelaborated" version. This altered version, embodying inserted segments which used the procedures of intentional learning, was responded to with distinctly positive attitudes by mature adults. No difference in favorable attitude was found between the groups which viewed the original and the elaborated version of the program. Yet the latter group exhibited a significant increase in their knowledge of natural selection and its social consequences.

A word needs to be said concerning the learning we have observed in groups of adults of retirement age. Those who volunteered to view these programs on a science subject certainly showed no apparent diminution in their eagerness to learn or their ability to learn. Of course this study collected no data to make possible a comparison with other age groups. Nevertheless, the study may be viewed as one more example of undiminished learning ability on the part of older adults (Arenberg & Robertson-Tchabo, 1977).

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THE ELDER HOSTEL STUDY

Adult Reactions to TV Science Programs

Ernest Burkman and Robert M. Gagné

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Documentary television programs on scientific subjects, of which the NOVA series is an outstanding example, vary considerably in the degree to which their contents include general principles of science, as contrasted with descriptions of specific phenomena. Likewise, programs on scientific topics seldom deal with the societal roles and effects of science, as contrasted with the social effects of particular events. Some NOVA programs present contents which are very "sciency", while others are much less so, even when the phenomena they describe are undeniably legitimate objects of scientific observation and study.

An investigation was planned to use specially prepared versions of three NOVA programs, augmented by inserted portions designed to accomplish two purposes:

(1) to convey a number of general principles of science and science policy which could be exemplified by the regular portions of the program; and

(2) to inform viewers about techniques of learning and remembering, as implied by the idea of "metacognition" (Flavell, 1979).

Augmented portions of instruction on science principles, along with a few suggestions about learning and remembering, were delivered by a retired sports broadcaster, "Red" Barber, a popular communicator. The augmented versions with Barber's commentary were tried out for general acceptability on several elderly people in the local community, and were adjudged satisfactory.

The purpose of the planned investigation was to contrast the learning and retention of general science principles of a group which saw augmented versions of NOVA programs, with similar results from a group which viewed the "standard" versions of the same programs. The three NOVA programs selected and prepared for this usage were Pill for the People, Will the Fishing Have to Stop, and The Insect Alternative. The general principles to be taught and tested were as follows:

(1) Science activity produces scientific knowledge, which consists of descriptions of natural events and means for predicting and controlling them.

(2) A chain of processes relates science and its outcomes to societal impact. Generally, the chain begins with basic research, proceeds to applied research, to product development, and to ways of improving the quality of life.

(3) The payoff of basic research is the ability to predict natural events under various conditions.

(4) The payoff of applied research consists of the model of a product which is capable of improving the quality of life.

(5) For basic research, it may not be possible to foresee any particular application. Nevertheless, applied research and its products are dependent upon the discoveries of basic research.

(6) In general, applied research attracts industry support; basic research does not. Basic research provides the foundation for applied research and product development. Therefore, public support should be provided for basic research.

(7) When a product is developed, certain side effects occur because of incomplete knowledge about the system being studied.

(8) Research is also conducted to compare the risks of side effects with the benefits expected for a product.

(9) There is a continuing need for monitoring side effects by public agencies, and regulation when risks become too great.

(10) When science tries to adjust systems composed of living things, special problems are encountered. All living systems are composed of parts that interact with each other so that the system as a whole is self-regulating.

(11) Changes introduced in a part of a living system are very likely to produce negative side effects in other parts of the system.

(12) Self-regulation means that any change in one part of a system affects another part, which reacts in such a way that the first part returns to its initial state, maintaining the balance of the system as a whole.

The opportunity provided for the study was the scheduling of two Elder Hostel courses by the Center for Professional Development and Public Service, Florida State University. These five-day courses, each entitled "Science in the Real World" were held in two successive weeks beginning June 22, 1981. Each of these courses was to be attended by a group of about 32 students. In general, these were highly educated people, of approximate age range from 55 to 75.

The Viewing Sessions

The course containing the viewing sessions for the specially prepared programs began with a class on "Florida Coastal Ecology" by a biologist who specializes in this field and who is an inspiring lecturer. On the second day, the augmented program Pill for the People was shown, with a suitable introduction explaining the purpose of this component of the course,

and inviting cooperation with the goal of improving TV science programs. Although there were some joking remarks about the anomalous content (birth control) for this age group, students were reminded that the scientific, rather than the personal, aspects of the programs were intended as course emphases. At the same time, some audible grumbling could be heard, apparently over the fact the TV was being presented, rather than a live lecturer.

On day three, the augmented TV program Will the Fishing Have to Stop? was presented. Within a matter of minutes, however, the grumbling turned to overt complaints, again expressed as dislike for TV programs as opposed to live lectures. Some students left the class before the period ended. The experimenter stopped the TV presentation before its end, and listened to complaints. It was apparent that re-planning of the course needed to take place immediately, because the students said they would not attend another TV session.

Following this class period, plans were made to conduct a fourth class as a live lecture on "Human Memory", and to follow this on the fifth day (as originally planned) with a live lecture on "Chemistry and Nuclear Power". These plans were carried out for the June 22-26 course. For the June 29-July 3 class, live lectures and demonstrations were employed throughout.

Investigating Reactions to TV Science Programs

Participants

The number of students attending the first Elder Hostel session, during which dislike of the TV programs was expressed, was 30; 10 males and 20 females. Their ages were 57 to 79, with a median of 67. Highest grade attained in education ranged from 11 to 22, with a median of 14; the number with at least a 4-year college education was 12 out of 30. Median pre-retirement income was reported to be $22,000. Evidently, these students were

much above average in intellectual resources and competence. Their reactions were almost certainly affected by this circumstance.

Procedure

Several months were permitted to pass by, before requesting the students in this class to respond to a questionnaire. The latter instrument was designed to find out what specific aspects of the programs produced negative reactions, the quality of the program, the choice of the TV commentator, the topics being presented, or the general lack of preference for TV versus live lecture. Participants were asked to check one of four degrees of satisfaction, very satisfied, satisfied, unsatisfied, and very unsatisfied, with respect to each of the following nine features:

(1) My overall impression of the TV science program that we were shown

(2) Using television to give instruction

(3) Using a lecturer to give instruction

(4) The topics of the TV programs

(5) The quality of the TV programs

(6) The manner of presentation by the TV commentator

(7) The material presented by the TV commentator

(8) The choice of TV commentator

(9) The viewing conditions of the room where the TV program was shown

In mid-November, letters were sent to the members of the class, reminding them of the two TV programs they had seen, and of the fact that some members of the class expressed a strong negative reaction. The letters asked for responses to and return of the nine-item questionnaire, by way of enclosed stamped self-addressed envelopes. Each letter stated "We hope you will help us think out the problem of what kind of instruction most appeals to people like yourself".

Results

The number of replies received was 24. Since the number of class members was 30, this represents a return of 80%.

Responses to this questionnaire are summarized in Table 1. Percent of responses in the four degree-of-satisfaction categories are indicated for each of the nine presentation features. A final column gives a summary percent of responses that are satisfactory, unsatisfactory, or mixed.

The most clearly marked contrast, as Table 1 shows, is between lecture and television. Members of this class overwhelmingly preferred to receive instruction via lecture. The topics of the TV programs were not generally disliked; at least, reactions to them were mixed. Definite negative reactions, however, were made to the quality of these programs, including particularly the augmented portion delivered by the commentator. It is notable that there was no consensual negative reaction to the commentator himself. The added contents pertaining to science principles, however, were considered unsatisfactory.

Discussion

Two circumstances appear to be important for the interpretation of these results, the first specific and the second more general in origin. The favorable reaction to lecture was probably influenced to some degree by the fact that on the first day of the course the members heard an inspiring lecturer discourse on a familiar topic of local concern and interest (Florida ecology). The second day's presentation by television (Pill for the People), although not inherently uninteresting, was surely a topic of less immediate and personal interest to these students. In addition, the inserted portions with the TV commentator doubtless had a more didactic quality than did the lecturer's dynamic presentation.

Table 1

Responses to Questionnaire Items by

Elder Hostel Class Members (S = Satisfactory; U = Unsatisfactory)

Feature	N	Very S	S	U	Very U	Summary
Overall Impression	24	4%	13%	38%	46%	84% U
TV as Medium	24	8%	8%	46%	38%	84% U
Lecture as Medium	23	61%	30%	0%	9%	91% S
Topics of TV Programs	22	4%	36%	18%	41%	Mixed
Quality of TV Programs	24	4%	21%	33%	42%	75% U
Commentator Presentation	23	9%	26%	30%	35%	65% U
Commentator Material	22	4%	23%	36%	36%	72% U
Choice of Commentator	22	4%	36%	41%	18%	Mixed
Viewing Conditions	24	8%	62%	17%	12%	70% S

A second reason for the lecture preference may well have greater general significance, although its validity cannot be verified by the present results. Elder Hostel students who enroll in a course entitled "Science in the Real World" (or in many other courses) expect to hear lectures. As is well known, listening to the oral communications of lecturers makes no great demands of mental effort. The amount and "depth" of cognitive processing (Craik & Lockhart, 1972) is under the control of the individual student, and may be slight or great, depending on the motivation prevailing at the moment. It is likely that Elder Hostel students, who enroll in a course to be "further educated", wish to be able to maintain control over the manner and degree in which they will process the contents of a lecture.

In the context of this kind of course for this type of student, a TV program which aims at deliberate instruction does not produce a favorable reaction. Learning from educational TV programs seen at home is recognized as incidental learning, rather than intentional. Rarely does a TV documentary program encourage its viewers to learn, or contain the elements which impose the necessity of intellectual processing beyond what is usual for "incidental learning". Yet the purpose of deliberate learning was the aim of the two TV programs employed in this Elder Hostel course. This incongruity with the usual TV viewing may have contributed to the attitude of the students which was expressed in their unsatisfactory reactions.

There are, of course, strong traditions at work which favor the continuation of educational TV programs in the incidental-learning mode. The training grounds for television producers are oriented to commercial purposes and "entertainment" values. Even the well-known children's program Sesame Street depended upon indicators of "attention value" for content evaluation (Lesser, 1974) as opposed to measures of learning effectiveness.

The current study has not managed to answer the question with which it began: namely, can the learning effectiveness of educational TV science programs be enhanced by augmenting features designed for deliberate support of intentional learning? In fact, the results support the speculation that in the future, most adult learning may take place incidentally via participation in programs which are designed as entertainment.

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THE TALLAHASSEE STUDY

Adult Retention of Ideas from a TV Science Program

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A substantial amount of research has been devoted to the identification of favorable conditions for adult learning and remembering (Craik, 1977; Arenberg & Robertson-Tchabo, 1977; Knox, 1980). As Neisser (1982) points out, many studies have been performed in laboratory settings with laboratory tasks, whereas much is yet unknown about remembering as it occurs in natural contexts.

For the mature adult learner, a natural context for remembering frequently begins with the in-home viewing of a television program. Such a session of learning contrasts markedly, not only with the conditions of a laboratory setting, but also with the nature of the content that is likely to exist between the conditions set up in the laboratory for intentional learning, and those established by a typical TV educational documentary program, which are generally agreed to be appropriate for incidental learning (Gallagher, 1978).

When a television documentary, such as one on a scientific topic, is viewed in a naturalistic setting, the viewers may be attending to the content and attempting to comprehend it. At the same time, incidental learning is taking place. A residue of what has been viewed is "laid down" in the memory, and when this is later revealed as remembered content, it becomes evidence that learning has occurred. At the present time, it appears that we know very little about what is learned and remembered from the viewing

of TV documentary programs. We have no theoretical basis for the prediction of how much will be learned, what kinds of things will be remembered, and how long they will be remembered. This lack of systematic knowledge applies whether we focus on memory for verbatim recall (Rubin, 1977), the "gist" of stories (Dube, 1982), or the framework which reflects both traditional and personal aspects, usually called a schema (Bartlett, 1932; Anderson, 1977).

The purpose of the present study was to investigate the nature of remembering in a typical group of elderly adults who were viewers of a TV documentary science program. We were interested in discovering, if possible, how much was learned, whether main ideas or details, whether the ideas were literally conveyed or inferred by the viewers, and whether any decrement in recall occurred over a two-day period.

The setting for the study was chosen to be naturalistic, but involving some particular constraints. The viewing and recall testing was done in groups, not individually in the home. The viewers were told they would be asked questions subsequently to the program viewing session. Conforming to naturalistic conditions, however, was the fact that remembering was carried out as cued recall. Constructed answers were called, for, rather than the recognition of multiple choice statements. It is evident that any and all of these particular conditions may affect the results obtained. Only additional carefully designed research will yield information about such effects. Meanwhile, the present study does provide some organized information and conclusions about the remembering by adults of the kinds of science programs that are often available today.

Method

Participants

Fifty-nine mature adults participated in the study. They viewed the TV science program in 8 different sessions, ranging from 3 to 11 people

per session. The various sessions were held in a Tallahassee retirement center, under the auspices and with the cooperation of the local chapter of AARP. With due provision for personal schedules, random assignment of the viewers of each session was made so as to form two experimental groups, one of 20 and the other of 39.

The characteristics of these two experimental groups, in terms of age, education, and income prior to retirement, are shown in Table 1. By inspection, the groups appear reasonably well matched, and there are no statistically significant differences in their means and S.D.'s. Summarizing the statistics for both groups combined, the range of ages was 56-83, with a mean of 70; highest grade of education ranged from 9 to 18, with a mean of 13.5; and family income prior to retirement ranged from less than $10,000 to more than $25,000 with a mean of $15,000.

Materials

TV Program. A NOVA Science program entitled The Insect Alternative, on videotape, was edited to form a presentation of 30 minutes in length. The edited version provided a smoothly flowing narrative which maintained the continuity of the literal content.

Contents of the sound track were subjected to a text analysis procedure as described by Meyer (1975). Using this technique, a total of 1317 ideas were identified, of which 315 were main ideas and 1002 subordinate ideas.

Test of Recall. The test employed for remembering was made up of 36 items, each an incomplete statement with a blank to be filled in by a word or phrase. Recall of main ideas was assessed by a random sample of 14 items, and of subordinate ideas by a random sample of 14 of those ideas. Remembering in the sense of inferences from the literal content was represented by 8 items devised by a biological scientist well acquainted with the program

Table 1

Age, Education, and Pre-Retirement Family Income Statistics of the Two Groups of the Experiment

Measure	Age		Education[a]		Prior Income[b]	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Mean	69.9	71.5	13.21	14.25	2.87	3.45
S.D.	5.9	5.8	4.56	4.64	1.39	1.43

a. Highest grade completed

b. 2 = $10,000 - $14,999; 3 = $15,000 - $19,999

and with the field of insect control, These three sets of items were combined into a single test, arranged in a sequential random order.

The following are the three types of items, with expected fill-in answers and alternative answers indicated in parentheses.

Main ideas. 1. Most insects eat (plants) (foliage), while some insects eat other insects.

2. The pear psylla damages pear trees because of the transmission of (disease).

3. The pesticide first developed during World War II and later banned was (DDT).

4. The tiny insect that makes citrus fruit surfaces spotty is the (red scale) (spotted scale).

5. Some insecticides kill insects by penetrating the insects' (skin) (shell).

6. The first response of growers to the problem of insect resistance was to change or increase the use of (insecticide).

7. Caterpillars were used in the search for a chemical that will stop production of the (juvenile) hormone in insects.

8. The industry of Mexico which was wiped out by an insect was the (cotton) industry.

9. Heavy use of insecticide often kills both pest insects and (beneficial) (friendly) insects.

10. The postwar agricultural revolution in America was caused by mechanization, irrigation, and the production of (fertilizer).

11. Questions about use of insecticide were raised in the book Silent Spring written by (Rachel Carson).

12. Fillmore, California citrus growers control pests by releasing (wasps) in the groves.

13. There are more than (one million) known species of insects, and an equal number not even named yet.

14. In the 1920's, insect poisons were based upon the chemical element (arsenic).

Subordinate ideas. 1. In California's Imperial Valley, irrigation and a long hot growing season help produce the Nation's largest crop of (cotton).

2. The insect that is the major pest in California's growing field is the (pink bollworm).

3. The Green Lacewing is harmless as an adult but in the (larval) stage it eats thousands of aphids.

4. To count the boll weevils in a soil sample, the sample is put through a (sieve) (mechanical shaker).

5. As an adult, the Green Lacewing feeds primarily on (nectar).

6. To reduce boll weevils, growers plant a variety of cotton that matures (early).

7. Spraying for pear psylla is done in the (winter) (egg-laying) season, when females are out on branches.

8. Entomologists discovered that (over-wintering) (winter hibernation) is the weak link in the boll weevil life cycle.

9. A warning to the U.S. was brought about by the occurrence of an agricultural disaster in which other country? (Mexico)

10. Pheromone attracts males of the same species through what sense? (smell)

11. The part of the female pear psylla that is examined to help in determining when to begin spraying is the (abdomen) (ovary).

12. To test the effectiveness of pheromone, a separate trap was baited with (females).

13. The pear tree branch is struck three times with a stick in order to determine the (insect population).

14. Mechanical tractors paint cotton plant leaves with miniature plastic dispensers of (pheromone) (female sex smell).

Inferential ideas. 1. Pesticides which kill insects generally leave behind insects which are (resistant).

2. The aim of biological control agents is to interfere with some aspect of the insect's (life cycle) (development) (growth).

3. Even when a new pest control method is available, problems of cost can prevent its (use) (implementation).

4. Populations of insects are cut down following application of insecticide, but seldom is the (population) eliminated.

5. Chemical methods of insect control are often harmful because they produce (side effects) (resistant strains).

6. Besides chemicals and hormones, insects in crop fields can be killed by introducing (insects) (insect enemies).

7. Applied research on insects as opposed to basic research is usually conducted by (industry) (business concerns).

8. The study of an insect's (life) (behavior) provides clues for developing methods to control it.

Procedure

All viewing and testing was done in the senior-citizen center, a place well known to the participants. In the viewing room, several television monitors were placed so that each participant could easily see and hear the program. Between one and four people viewed each monitor screen.

The 30-minute edited version of The Insect Alternative was presented. Following this, participants in Group 1 were given test instructions for

completion of the recall test, while those in Group 2 were asked to return to the same place in two days' time. Upon their return, the recall test was administered to the individuals in Group 2.

Scoring of the recall test was done within each group for the components Main Ideas, Subordinate Ideas, and Inferential Ideas.

Results

Recall scores for the two groups, which reflect remembering immediately after viewing the program and two days later, are shown in Table 2.

Main Ideas

About 54% of the main ideas of the program were remembered immediately, and 53% after two days. The differences here are very small, and a *t*-test indicates no significant difference ($t=.65$) in the means. Thus, slightly more than half of the ideas of the program were learned and remembered, both immediately and over a 2-day period.

Subordinate Ideas

As Table 2 indicates, the same percentage (54%) of subordinate ideas was remembered by these adults, as indicated by scores on the immediate test of cued recall. A somewhat greater loss (down to 48%) was suffered by these ideas, however. The difference between means in this case is a significant one ($t=3.64$; $p < .01$). Subordinate ideas were initially remembered as well as main ideas, but their retention was significantly diminished after two days.

Inferential Ideas

About 5 out of 8 of the inferential ideas phrased as questions were correctly answered. Actually, slightly more were answered correctly after two days, but this is not a significant difference. It is tempting to speculate that inference may actually improve after "thinking things over" for two days. At any rate, the results certainly do not indicate a decrement

Table 2

Means and Standard Deviations of Cued Recall Scores on Three Types of Items for Immediate and Two-Day Remembering

Idea Type	Group 1 - Immediate (N = 39)			Group 2 - Two-day (N = 20)		
	%	M	S.D.	%	M	S.D.
Main	54	7.56	2.98	53	7.40	2.33
Subordinate	54	7.62	3.35	48	6.65	2.13
Inferential		4.92	2.16		5.25	1.91

in this inferential kind of learning and remembering. Assigning a percentage to the mean recall performance would in this case have only a trivial significance, since the amount recalled depends on the selection of particular items. This contrasts with the percentage figures for main and subordinate ideas, which carry the meaning that about half of the ideas communicated by the TV program were remembered.

Discussion

There is, first of all, the finding that slightly more than half of the ideas of the TV documentary were learned and remembered in the immediate sense. This finding corresponds closely with that of Owens (1981), employing a different half-hour documentary program with elderly adults. It appears that we may be gaining confidence in the answer to the question, "Under reasonably motivated conditions, and with fairly well-educated adults, how much is learned and remembered from incidental learning in watching a half-hour TV documentary?" Answer: about half.

Other findings are of at least equal interest. Main ideas of a program are remembered very well over two days, while subordinate ideas suffer some decrement. Obviously, we need additional research to learn more about the amount and kind of remembering over longer periods of time. The loss of subordinate ideas, in contrast to main ones, accords with some modern cognitive theories of memory, particularly the ideas of network links and the concept of spreading activation (Anderson, 1980). Main ideas are considered to have larger linking networks in memory than do subordinate ideas, and for this reason are more readily retrieved.

Adults having as much education as those in this study have little difficulty in drawing inferences from the literal text which has been presented. Presumably, the ease with which such inferences are drawn will depend upon the general intellectual level of the viewers, and also upon the amount of

relevant information (that is, related to insects and their control) previously stored in the individual's memory. While the data of the present study yield no specific results of this sort, the requirements of additional research along these lines are made apparent.

It is worthy of note that the NOVA program employed in this study, while it contains a reasonable number of "main ideas", does not make explicit the scientific principles which are identified as "inferential ideas". This is typical of nearly all NOVA programs. It is a research question of interest to ask whether these more general principles would be better learned, or more widely learned, were they to become a part of the literal content of the TV program. Such statements could be so treated, either by being given emphasis as "main ideas", or by being merely mentioned briefly. For the field of science education, these remain important questions to be answered.

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APPENDIX A
PROPOSED CONTENT FOR TV SCIENCE PROJECT

A. The Nature of Science

1. The goal of science is to describe nature and/or to predict and/or control the behavior of natural processes.

2. The key tools of scientists are observations and measurements. Emotional beliefs are considered suspect until verified by empirical evidence.

3. At any time, scientists' understanding* of nature and natural processes is limited by the observations and measurements that have been made to date. As new observations and measurements are made, their understanding changes and so do their descriptions. Normally, this results in more accurate predictions as to the behavior of natural systems and greater capacity for controlling them.

B. The Nature of Natural Processess

1. Natural Processes tend to be complex homeostatic systems. When one adjusts one part of such systems other parts of the system tend to get out of balance. This is especially likely if one is dealing with a process that is not well understood (i.e., one on which basic research has yielded poor capacity to predict and control.)

C. Science and Society.

Typically science impacts on society in this way:

1. The process begins with basic research aimed at describing how some natural process works. The payoff for this kind of research is the ability to predict accurately the behavior of the process under differing conditions and ultimately to be able to control its behavior.

* And, therefore, their ability to accurately describe nature or to predict or control natural processes.

2. At some point, the ability to predict and control certain natural processes becomes great enough to permit the process to be adjusted in ways that will increase people's standard of living. Applied research is concerned with uncovering ways to do this. The payoff for applied research is prototype products that alter natural process in ways that improve standards of living.
3. Once a prototype product is available, small scale tests are made to determine if it produces the results that are intended. At this point, basic research is begun to determine what kinds of side effects also result.
4. If the prototype testing results are promising, testing is extended to larger populations. These tests include measures of attitudes toward the use of the product, as well as measures of its effect. Side effect studies are continued.
5. If testing indicates that the product produces the intended result, and that there is a potential market large enough to generate a profit, design of systems for mass production and marketing begins.
6. If economically feasible mass production and marketing systems can be generated, dissemination of the product is undertaken. In some cases, regulatory agencies have been setup to examine side effect possibilities. If this is the case, then the marketing company may be required to submit data showing that negative effects are minimal or non-existent.
7. Throughout the process of product development and after its release, basic research and side effects research continues. Sometimes the research reveals unforeseen side effects that are serious. If the product is within the jurisdiction of a regulatory agency risk-benefit research is

out to determine if the product's advantages outweigh its disadvantages. If no agency is responsible, this work is left to individual scientists. If risk-benefit studies reveal an unacceptable risk, then a decision must be made regarding the continued use of the product. Decisions of this kind are most difficult, because of the large investments that have been made and the vested interest of the public in the improvement in the standard of living.

APPENDIX B
REVISED TEST ITEM DOMAINS

A1. Science activity produces scientific knowledge, which consists of descriptions of natural events and means for predicting and controlling them.

A2,3. A chain of processes relates science and its outcomes to societal impact. Generally, the chain begins with basic research, proceeds to applied research, to product development, and to ways of improving the quality of life.

A4. The payoff of basic research is the ability to predict natural events under various conditions.

A5. The payoff of applied research consists of the model of a product which is capable of improving the quality of life.

A6,7. For basic research, it may not be possible to foresee any particular application. Nevertheless, applied research and its products are dependent upon the discoveries of basic research.

A8. In general, applied research attracts industry support; basic research does not. Basic research provides the foundation for applied research and product development. Therefore, public support should be provided for basic research.

A9. When a product is developed, certain side effects occur because of incomplete knowledge about the system being studied.

A10. Research is also conducted to compare the risks of side effects with the benefits expected for a product.

A11. There is a continuing need for monitoring side effects by public agencies, and regulation when risks become too great.

B7. 7 When science tries to adjust systems composed of living things, special problems are encountered. All living systems are composed of parts that interact with each other so that the system as a whole is self-regulating.

B8. Changes introduced in a part of a living system are very likely to produce negative side effects in other parts of the system.

B9. Self-regulation means that any change in one part of a system affects another part, which reacts in such a way that the first part returns to its initial state, maintaining the balance of the system as a whole.